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Evaluating the implementation of Electronic Medical Record (EMR) Systems from the perspective of Health Professional

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Abstract

In health informatics, the "updated DeLone and McLean IS Success Model" is reviewed as a mature model in measuring health information system (HIS) success. This research provided an evaluation model to estimate the implementation of Electronic Medical Records (EMR) systems from a health professional perspective by combined the updated DeLone and McLean IS success model, data quality management model, and EMR systems safety attributes. Based on evidence-based management (EBM), this research could be regarded as an empirical example for further EMR systems research since it not only provided a model to measure the Taiwanese EMR systems in two hospitals by implementing a structure instrument and Structure Equation Modeling (SEM) of quantitative methods, but also introduced how to identify the possible effects in such evaluation research.

1. Introduction

Health Information System (HIS) evaluation reflects on the relationship between the system user, technology, and medical environment [1]. HIS evaluation is not only a key consideration in determining whether a HIS is accepted by health professionals, but also whether the use of HIS helps/hinders the realization of such goals in a real medical environment. An Electronic Medical Records (EMR) system is a part of HIS, so the establishment of a comprehensive, successful, high task fit and highly acceptable EMR system will help healthcare professionals to improve efficiency, effectiveness, and reduce medical errors. Adoption of EMR could lead to better quality and more efficient healthcare, consequently an EMR system contains sensitive health data of individual patients.

However, investing an EMR system is a costly process in hospitals; in addition, the failure to implement EMR systems could be attributed to developers ignoring stakeholder needs in hospitals [2]. The evidence-based management (EBM) could be used to generate and estimate the required supervision information in healthcare administration [3]. Health professionals are key stakeholders (end-users) in patient care [4]; based on EBM, HIS evaluation becomes an important topic in both health informatics and healthcare administration to realize the possible potential benefits to its stakeholders.

The Declaration of Innsbruck suggested that evaluation studies should be grounded on scientific theory and rigorous approaches [1]. Selecting a suitable method and evaluation instrument is a challenge in any HIS evaluation study; nevertheless, it needs to consider the goals (i.e. what to evaluate), and methods (i.e. how to evaluate) [5]. This research adopted "goal-based evaluation" [6] which focuses on realizing the possible benefits from a health professional perspective of a current-generation EMR system in Taiwan.

2. Conceptual Evaluation Model

Developing, adopting and promoting EMR systems are national goals in Taiwan [7]. The development of EMR systems helps health professionals to enhance patient care and clinical services [8], so the developers of EMR need to consider how to establish a useful system for storing patient data based on the feature of hospitals. Moreover, regarding clinical data of EMR and the development of both intranet and internet, clinical data quality [9] and safety quality [10] are both important issues in an electronic environment. Furthermore, HIS evaluation methods were derived from IS evaluation [11]. The Structure-Process-Outcome (S-P-O) model [13] of healthcare

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administration has been adopted in IS and HIS research [12]. Hence, it is essential to consider how to combine and integrate the above issues in evaluating the Taiwanese EMR.

In order to achieve our target, this study combined and revised the S-P-O model, the "updated DeLone and McLean IS success model" [14], contents of clinical data quality [9], and "Safety Quality"[10] to generate a comprehensive model in evaluating the Taiwanese EMR systems from a health professional perspective (Figure 1).

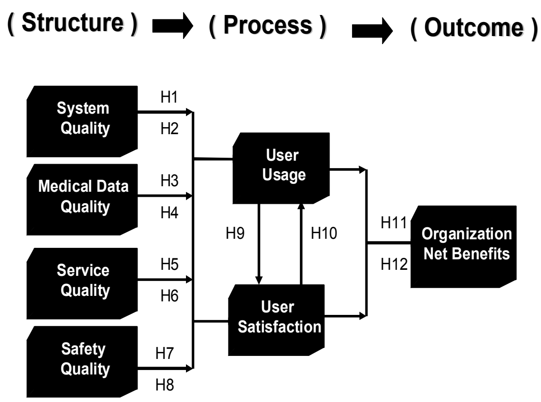

Figure 1 Evaluation Model

Based on the S-P-O model, Technology (Structure) aspects included Sys_Q, MDQ, Ser_Q, and Safe_Q; Human (Process) aspects covered UU and US; Benefits (Outcome) aspect is ONB. It supposed that UU and US of implementing EMR will be positively affected by Sys_Q, MDQ, Ser_Q, and Safe_Q; there is also an interaction between UU and US. Furthermore, UU and US will have a positive influence on ONB by implementing EMR in clinical service. The detailed definitions of this model are shown in Table1. In addition, this research also postulated twelve hypotheses:

H1: Sys_Q will have positive affects on UU.
H2: Sys_Q will have positive affects on US.
H3: MDQ will have positive affects on UU.
H4: MDQ will have positive affects on US.
H5: Ser_Q will have positive affects on UU.
H6: Ser_Q will have positive affects on US.
H7: Safe_Q will have positive affects on UU.
H8: Safe_Q will have positive affects on US.
H9: UU will have positive affects on US.
H10: US will have positive affects on UU.
H11: UU will have positive affects on ONB.
H12: US will have positive affects on the ONB.

Table 1 Definition of evaluation model

Dimension	Operational Definitions
System Quality (Sys_Q)	Identifying end-users' opinions of the performance distinctiveness of the EMR processing it provides.
Medical Data Quality (MDQ)	Identifying end-users' opinions of the output information produced by the EMR.
Service Quality (Ser_Q)	Considering how to provide accessible help to the stakeholders of EMR by the technological vender based on identifying end-users' judgment.
Safety Quality (Safe_Q)	Identifying end-users' opinions of the ability of risk management of the EMR it proves.
User Usage (UU)	Measuring the extension use of the EMR it proves based on identifying end-users' judgment.
User Satisfaction (US)	Measuring the consequences of users' response by using the output information of EMR.
Organization Net Benefits (ONB)	Realizing the impact and goodness of implementing EMR in patient care performance based on identifying end-users' judgment.

3. Design and Method

Two hospitals cooperated with this research in southern Taiwan. Hospital A is a medical center which is an acute care hospital with more than 1200 general beds; it adopted a Tandem server without Oracle Database to run its HIS/EMR. Hospital B is a regional teaching hospital which is also an acute care hospital with more than 400 general beds; it adopted a Dec Alpha 4000 server and Oracle Database to run its HIS/EMR. They both provide integrated hospitalized and clinic medical service in its location. They both also use the same EMR system due to the same operational strategies adopted for promoting e-health. However, because the servers are different, the current HIS/EMR in these hospitals are independent; top managers wish to integrate those systems into the same server before 2011and hence have both adopted Oracle. Accordingly, based on the EBM, this research was undertaken to measure the success, high task fit and acceptability of the existing EMR system for managers in these two hospitals.

This research focused on health professionals (physicians and nurses) who need to use EMR systems in their daily work were invited as participants to join this survey. In addition, an evaluation instrument was developed to collect data for testing the aforementioned research hypotheses. Based on our previous work of designing an appropriate Taiwanese EMR systems evaluation instrument, the reliability and validity of it has been identified[15]. This research used sixty-one structured questions and a free-text question to achieve our target; answers were assigned a value of 1 to 5 from “strongly disagree” to “strongly agree” by using the Likert-scale format. Participants were requested to fill out this instrument anonymously from 1st January to 31st March 2007.

Descriptive analysis displayed characteristics of participants, Reliability analysis was used to measure whether all questions follow the same trend, and one-way Analysis of Variance (ANOVA) was used to test whether there is a significant difference between two hospitals; these analyses were conducted using the “Statistic Package for the Social Science 15.0 (SPSS 15.0)”. Moreover, the AMOS 7.0 software program [16] was used to estimate research hypotheses by performing Structure Equation Modeling (SEM).

4. Results

In hospital A, 175 participants joined this research. Due to 15 participants not completing the entire questionnaire, 160 usable ones were used as research samples for data analysis. In Hospital B, 323 participants answered this instrument; however, for the same reasons as Hospital A; 301 usable ones were used as research samples (Table 2).

Table 2 Characteristics of participants

Characteristic / Hospital	A (N=160)	B (N=301)
Gender	N (%)	
Male	18 (11.25)	45 (14.95)
Female	142 (88.75)	256 (85.05)
Age		
20 ~ 40 years old	148 (92.50)	278 (92.36)
41^+ years old	12 (7.50)	23 (7.64)
Job title		
Physician	26 (16.25)	79 (26.25)
Nurse	134 (83.75)	222 (73.75)
Education		
Junior College	46 (28.75)	127 (42.19)
Bachelor (includes MD)	108 (67.50)	149 (49.51)
Master and Doctoral	6 (3.75)	25 (8.30)
Seniority		
Less than one year	15 (9.38)	30 (9.97)
1 ~ 5 years	70 (43.75)	123 (40.86)
6 ~ 10 years	29 (18.13)	124 (41.20)
11 ~ 15 years	26 (16.25)	18 (5.98)
16^+ years	20 (12.50)	6 (1.99)

Based on the suggestion of Reliability analysis, the value of Cronbach’s alpha needs to be greater than 0.80 [17]. Table 3 shows that both in single or overall dimensions, all data exhibited highly internal consistency. Moreover, participants in Hospital B are more satisfied with their EMR system than the Hospital A; there are significant differences between seven dimensions in both hospitals.

Table 3 The results of Reliability test and ANOVA

Dimensions	Items	Hospital A	Hospital B
Sys_Q	9	0.94**	0.92**
MDQ	10	0.96**	0.97**
Ser_Q	7	0.93**	0.96**
Safe_Q	11	0.93**	0.94**
UU	8	0.90**	0.90**
US	9	0.94**	0.94**
ONB	7	0.94**	0.94**
Overall	61	0.98**	0.98**
	ANOVA	Mean (SD)	Mean (SD)
Sys_Q	0.00**	3.14 (0.86)	3.50 (0.69)
MDQ	0.00**	3.35 (0.82)	3.61 (0.62)
Ser_Q	0.00**	2.76 (1.06)	3.38 (0.71)
Safe_Q	0.00**	3.36 (0.87)	3.60 (0.63)
UU	0.00**	3.23 (0.96)	3.47 (0.74)
US	0.00**	3.34 (0.90)	3.52 (0.68)
ONB	0.00**	3.30 (0.92)	3.52 (0.74)

** $p< \alpha=0.01$

The validity of this evaluation instrument has been identified [15], so Confirmatory Factor Analysis (CFA) was performed to determinate which questions were suitable for SEM [18]. Previous researches [19, 20] have indicated that a measure model should be conducted by the goodness of fit (GOF). In this research, GOF was evaluated using the chi-square statistic, the chi-square to degrees of freedom ratio, the comparative fit index (CFI) [21], the Tucker–Lewis Index (TLI) [22] and the root-mean-square- error of approximation (RMSEA) [23]. The assessment of SEM is also achieved using by the same criteria [20]. In addition, researchers have suggested that the ratio of X^2/df (likelihood ratio) should be 3 or smaller, it indicating acceptable fit between the hypothetical model and the sample data [24]. Compared with a more restricted baseline model, The CFI and TLI are incremental fit indexes that measure the proportionate improvement in model fit of the target model. The value of CFI and TLI should be grater than 0.95, which indicates a good fit between the observed data and the hypothesized model [25]. The RMSEA is an absolute fit index, the value of which should be below 0.08; if so, it could be regarded as indicating a good fit between the observed data and the specified model, which assesses how well a model reproduces the observed sample data [26]. The results of GOF and hypotheses test of the evaluation model are shown in Table 4.

Table 4 The results of GOF and hypotheses test

Criteria	Hospital A		Hospital B	
	(1)	(2)	(1)	(2)
X^2	374.467	8.004	629.584	12.230
df	11	5	10	5
X^2/df (<3)	34.402	1.601	62.985	2.446
CFI (>0.95)	0.613	0.997	0.569	0.995
TLI (>0.95)	0.261	0.987	0.950	0.979
RMSEA (<0.08)	0.456	0.061	0.454	0.069
Hypotheses	(3)	(4).	(3)	(4).
H1 (UU ← Sys_Q)	--	--	0.47**	9.20
H2 (US ← Sys_Q)	--	--	0.26**	4.51
H3 (UU ←MDQ)	--	--	--	--
H4 (US ← MDQ)	0.28**	4.29	0.12**	2.22
H5 (UU ← Ser_Q)	0.38**	6.42	0.18**	3.42
H6 (US ← Ser_Q)	0.20**	3.03	--	--
H7 (UU ← Safe_Q)	0.48**	8.00	0.20**	3.99
H8 (US ← Safe_Q)	--	--	--	--
H9 (US ← UU)	0.44**	5.76	0.52**	11.10
H10 (UU ← US)	--	--	--	--
H11 (ONB ← UU)	0.46**	6.08	0.36**	6.43
H12 (ONB ← US)	0.56**	9.51	0.44**	8.01
R^2 for UU	0.60		0.53	
R^2 for US	0.65		0.65	
R^2 for ONB	0.74		0.60	

(1) Initial model
(2) Revised model
(3) Standardized regression coefficient;
(4) Critical Ratio (C. R.);
-- Rejected in revised model;
** Statistically significant (p< α=0.01)

As shown in Table 4, the GOF of the revised model was considerably better for the initial model. Taking Hospital A for instance, the X^2, likelihood ratio and RMSEA dropped from 374.467 to 8.004, 34.402 to 1.691, and 0.456 to 0.061, respectively. In addition, CFI and TLI increased from 0.613 to 0.997 and from 0.261 to 0.987, respectively. With regard to results of GOF, Table 4 also displays Standardized Regression Coefficient and Critical Ratio of revised model. In Path analysis, only statistically significant results (p<.05) were accepted in revised model; otherwise they were deleted from this research model. Finally, hypotheses H4, H5, H7, H9, H11, and H12 were accepted in both hospitals. H1, H2, H3, H8, and H10 were rejected in Hospital A, and H3, H6, H8, and H10 were rejected in Hospital B. In short, the results of this study indicated in both hospitals: (1) UU was positively affected by Ser_Q and Safety_Q; (2) US was positively affected by MDQ, and UU; (3) ONB was positively affected by UU and US; (4) Safe_Q had no affect on US; (5) US had no affect on UU.

5. Discussion

Applying the structure of the S-P-O model, this study identified that technology (Structure) will affect humans (Process), and humans will affect an organization's net benefits (outcome). Considering the features of EMR system (a safety critical system), this research applied the "Data Quality model" to replace Information Quality, and added "Safety Quality" into the updated D & M IS success model. We conducted that both could be used in EMR system evaluation. Therefore, this model could be regarded as suitable for evaluating Taiwanese EMR systems. This empirical study not only shares our assessment experience in EMR systems evaluation by collecting practical data in two hospitals, but also provides an empirical example for further research.

For the EBM, results for H4, H5, H7, H9, H11, and H12 provided useful and detail information and a clear guideline for managers to understand the strengths and weakness of existing EMR system in both hospitals. Although the operational strategies adopted for promoting e-health are the same in both hospitals, they adopted the same EMR system, and receive the same training for patient care. The results of SEM were quite different between H1, H2, and H6.

Firstly, for hospital A, results shows that Sys_Q will not have a positive affect on UU and US; in other words, it means no matter how well or poor the processing of this EMR, Sys_Q will not affect the UU and US. However, compared with Hospitals A, Hospitals B has implemented e-health since it opened in 1998, hence health professionals are used to using HIS, so they consider that UU and US were affected by Sys_Q. It is important for managers to understand that health professionals are enforced to implement EMR system which is requested by its hospital, and the results of ANOVA also show that there are significant differences between both hospitals. It may be related to organizational behaviours/culture of hospitals, but needs further research to confirm this.

Secondly, the results show that health professional in Hospital B considered US were not directly affected by Ser_Q; however, there was an *indirect* affected (Ser_Q-->UU-->US; β=0.1). This means US of health professionals will happen after they use this EMR and the judgment of Ser_Q will depend on whether department of information system (DIM) staff could provide sufficient support and help to their request for patient care. Although Hospital A and B use the same EMR system, due to the main server and database being different between them, end-users in Hospitals A always complained that DIM staff cannot complete their requests for new applications and /or functions, design, expansion, and executions of this EMR during a reasonable and acceptable time frame. Therefore, this could be the reason why they considered UU and US to be directly affected by Ser_Q.

In addition, H3, H8, and H10 were statistically insignificant in both hospitals. For H3 and H10, it indicated UU was not affected by MDQ and US. In the sample hospitals, when end-users were requested to use EMR for patient care, MDQ and US had not affect on UU. H8, for the same reason as H3 and H10, US were not affected by Safe_Q.

Although H3, H8, and H10 were not accepted in this research, managers still can realize end-users opinion by analyzing returned instruments to identify possible potential effects of EMR. Reviewing the results provides information for managers and EMR developers to understand how end-users feel about existing EMR system. Managers can realize the overall satisfactions of MDQ, Ser_Q and US by analyzing each question of these dimensions; consider how to provide a success, high task fit and acceptability EMR system to satisfy with stakeholder needs in patient care by implementing a more appropriate EMR system.

6. Conclusion

In healthcare, HIS evaluation is regarded as the best way to recognize the potential effects of Information and Communication Technology (ICT) [27], so an evaluation study needs to focus on the features of specific systems and their effects on people and organizations [28]. Following this issue, an evaluation framework with twelve hypotheses in estimating EMR system from a health professional perspective was tested in two sample hospitals, using Reliability analysis, ANOVA, and SEM (CFA and Path analysis). By analyzing the results of the evaluation instrument and applying SEM to twelve hypotheses, the results of the data analysis display a clear relationship between "cause" and "effect" in implementing the EMR system.

Moreover, for EBM, results of hypotheses: (1) showing the significant difference between hospitals although they belong to the same organization; (2) showing what should be improved in the existing EMR system (statistically significant hypotheses); (3) showing the potential effects of using this EMR system, such as H3, H8, and H10 (statistically insignificant hypotheses).

In short, this model could be regarded as being suited to the local culture perspective guideline for evaluating the Taiwanese EMR systems. As we mentioned this framework is a flexible one, it definitely needs to be examined in different kinds of hospitals in Taiwan to make it more comprehensive and appropriate in evaluating the implementation of EMR systems from a health professional perspective.

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